TOXIC GAS MONITORING

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IM FLASH LIFE SAFETY AHJ
AGENDA

- Toxic Gas Primary Gas Hazards
- SemiConductor Industry Code Requirements
- Large Toxic Gas Monitoring Systems Block Diagram
- TGM Detection System Flow and Control
- Semiconductor TGM System Integration and Controls
- Types of TGM Detectors
- New Hazardous Production Materials (New Toxic Gas) Considerations
- Conclusions
PRIMARY GAS HAZARDS

- FLAMMABLE
- TOXIC
- ASPHYXIANT
- PYROPHORIC
FLAMMABLE GAS HAZARDS

- **Flammable Limit**
  - Each Flammable gas has a specific band of gas/air concentrations that will produce a combustible mixture, between the Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL).
  - Lower Explosive Limit – at levels below the LEL there is insufficient gas to produce an explosion, the mixture is too lean.
  - Upper Explosive Limit – Gas above the UEL the mixture has insufficient oxygen, the mixture is too rich to produce an explosion.
  - Toxic Gas Monitoring will be done by measuring percentage of LEL, for a specific gas.
Many gases used in the Semi-Conductor industry are poisonous and can be a danger to life at very low concentrations, some have physical warning properties like smells that will notify people of their presence. (i.e. Ammonia, NH3 has a distinct smell and you will get a burning sensation around your sweat glands) However most gases are odorless, or without physical warning properties below exposure limits.

Occupational Exposure Limits varies from Country to Country and in the US they even vary from State to State, in the US there are 3 major providers for setting the Occupational Exposure Limits - ACGIH, OSHA, and NIOSH for reference.

- ACGIH, (American Conference of Governmental Industrial Hygienists)
- OSHA, (Occupational Safety and Health Administration)
- NIOSH, (National Institute for Occupational Safety and Health)

TLV (Threshold Limit Value) is a reserved term of the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs issued by the ACGIH are the most widely accepted occupational exposure limits both in the United States and most other countries.
TOXIC GAS HAZARDS

- TLV of a chemical substance is a level to which it is believed a worker can be exposed day after day for a working lifetime without adverse health effects.
- The measurements most commonly used for concentrations of Toxic Gas levels are Parts per Million (PPM) and Parts per Billion (PPB).
- Typical Semiconductor Industry standards for Toxic Gas Monitoring would be to set Alarm Level 1 at ½ TLV and Alarm Level 2 at TLV.
  - TGM Level 1 Alarms Notify occupants of the potential hazard.
  - TGM Level 2 Alarms close HPM control valves and Notify Monitoring stations for response.
- (ACGIH) publishes Threshold Limit Values & Biological Exposure Indices.
Oxygen deficiency is another of the hazards that is present in manufacturing. Air is made up of several different gases including oxygen. Normal ambient air contains an oxygen concentration of 20.9%. When oxygen levels are below 19.5% the air is considered oxygen deficient, and below 16% it is considered unsafe for humans.

**Health Effects**

- **15%-19%** Reduced intellectual & physical performance, reduced coordination, and increased breathing rate.
- **12%-15%** Poor judgement, abnormal fatigue, emotionally upset.
- **<10%** Inability to move, fainting, almost immediate loss of consciousness, convulsions followed by death.
- **<6%** Convulsions, shortness of breath, cardiac standstill, death in minutes.
- **<4%** Unconsciousness after one or two breaths.
PYROPHORIC GAS HAZARDS

- **Pyrophoric Gas** - According to OSHA, “pyrophoric” means “a chemical that will ignite spontaneously in air at a temperature of 130 degrees Fahrenheit (54.4 degrees C) or below.

- Image of a Silane Release and Explosion at a Photovoltaic Fab, 1 Fatality.
PEL – Permissible Exposure Limit – 8 hour time weighted average of an airborne concentration of a substance and represents conditions in which all workers may be exposed to for 8 hours per day.

- Established by OSHA
- Most TLV’s and PEL’s are the same
  - New Arsine TLV established of 5ppb on Jan 1, 2007
  - Arsine PEL 50ppb

STEL – Short Term Exposure Limit – 15 minute time weighted average exposure that should not be exceeded at any time during a work day even if the 8 hour TWA average is within the TLV or PEL.

IDLH – Immediately Dangerous to Life and Health – Maximum airborne concentration in which a person could escape within 30 minutes without any escape impairing symptoms or irreversible health effects.

- This is does not represent a safe level of exposure

TWA – Time Weighted Average is used to calculate a workers daily exposure to a hazardous substance or agent, averaged to an 8-hour workday. This is a guideline to determine PEL’s.
PRIMARY TOXIC GAS MONITORING CODE REQUIREMENTS

- **IBC - 415.11.3 Service corridors.** Service corridors within a Group H-5 occupancy shall comply with Sections 415.11.3.1 through 415.11.3.4.
  - **IBC - 415.11.3.1 Use conditions.** Service corridors shall be separated from corridors as required by Section 415.11.1.2. Service corridors shall not be used as a required corridor.
  - **IBC - 415.11.3.2 Mechanical ventilation.** Service corridors shall be mechanically ventilated as required by Section 415.11.1.6 or at not less than six air changes per hour.
  - **IBC - 415.11.3.5 Emergency alarm system.** Emergency alarm systems shall be provided in accordance with this section and Sections 415.5.1 and 415.5.2. The maximum allowable quantity per control area provisions shall not apply to emergency alarm systems required for HPM.
    - **IBC - 415.11.3.5.4 Alarm-initiating devices.** An approved emergency telephone system, local alarm manual pull stations, or other approved alarm-initiating devices are allowed to be used as emergency alarm-initiating devices.
    - **IBC - 415.11.3.5.5 Alarm signals.** Activation of the emergency alarm system shall sound a local alarm and transmit a signal to the emergency control station.
- **IBC - 415.11.4 Storage of hazardous production materials.** Storage of hazardous production materials (HPM) in fabrication areas shall be within approved or listed storage cabinets or gas cabinets or within a workstation. The storage of HPM in quantities greater than those listed in Section 5004.2 of the International Fire Code shall be in liquid storage rooms, HPM rooms or gas rooms as appropriate for the materials stored. The storage of other hazardous materials shall be in accordance with other applicable provisions of this code and the International Fire Code.
IFC - 2703.13 Continuous Gas Detection System. A continuous gas detection system shall be provided for HPM gases where the physiological warning threshold level of the gas is at a higher level than the accepted permissible exposure limit (PEL) for the gas and for flammable gases in accordance with Sections 2703.13.1 and 2703.13.2.2.

IFC - 2703.13.1 Where required. A continuous gas detection system shall be provided in the areas identified in Sections 2703.13.1.1 through 2703.13.1.4

IFC - 2703.13.1.1 Fabrication areas. A continuous gas detection system shall be provided in fabrication areas where gas is used in the fabrication area.

IFC - 2703.13.1.2 HPM rooms. A continuous gas detection system shall be provided in HPM rooms where gas is used in the room.

IFC - 2703.13.1.3 Gas cabinets, exhausted enclosures and gas rooms. A continuous gas detection system shall be provided in gas cabinets and exhausted enclosures. A continuous gas detection system shall be provided in gas rooms where gases are not located in gas cabinets or exhausted enclosures.

IFC - 2703.13.1.4 Corridors. Where gases are transported in piping placed within the space defined by the walls of a corridor and the floor or roof above the corridor, a continuous gas detection system shall be provided where piping is located and in the corridor.

Exception: A continuous gas detection system is not required for occasional transverse crossings of the corridors by supply piping that is enclosed in a ferrous pipe or tube for the width of the corridor.
**IFC - 2703.13.2** Gas detection system operation. The continuous gas detection system shall be capable of monitoring the room, area or equipment in which the gas is located at or below all the following gas concentrations:

1. Immediately dangerous to life and health (IDLH) values where the monitoring point is within an exhausted enclosure, ventilated enclosure or gas cabinet.
2. Permissible exposure limit (PEL) levels where the monitoring point is in an area outside an exhausted enclosure, ventilated enclosure or gas cabinet.
3. For flammable gases, the monitoring detection threshold level shall be vapor concentrations in excess of 25 percent of the lower flammable limit (LFL) where the monitoring is within or outside an exhausted enclosure, ventilated enclosure or gas cabinet.
4. Except as noted in this section, monitoring for highly toxic and toxic gases shall also comply with Chapter 60 of the International Fire Code.

**IFC - 2703.13.2.1 Alarms.** The gas detection system shall initiate a local alarm and transmit a signal to the emergency control station when a short-term hazard condition is detected. The alarm shall be both visual and audible and shall provide warning both inside and outside the area where the gas is detected. The audible alarm shall be distinct from all other alarms.

**IFC - 2703.13.2.2 Shutoff of gas supply.** The gas detection system shall automatically close the shutoff valve at the source on gas supply piping and tubing related to the system being monitored for which gas is detected when a short-term hazard condition is detected. Automatic closure of shutoff valves shall comply with the following:

1. Where the gas detection sampling point initiating the gas detection system alarm is within a gas cabinet or exhausted enclosure, the shutoff valve in the gas cabinet or exhausted enclosure for the specific gas detected shall automatically close.
2. Where the gas detection sampling point initiating the gas detection system alarm is within a room and compressed gas containers are not in gas cabinets or an exhausted enclosure, the shutoff valves on all gas lines for the specific gas detected shall automatically close.
3. Where the gas detection sampling point initiating the gas detection system alarm is within a piping distribution manifold enclosure, the shutoff valve supplying the manifold for the compressed gas container of the specific gas detected shall automatically close.
PRIMARY TOXIC GAS MONITORING CODE
REQUIREMENTS

- **IFC - 2703.1 Emergency control station.** An emergency control station shall be provided in accordance with Sections 2703.1.1 through 2703.1.3.

- **IFC - 2703.1.1 Location.** The emergency control station shall be located on the premises at an approved location outside the fabrication area.

- **IFC - 2703.1.2 Staffing.** Trained personnel shall continuously staff the emergency control station.

- **IFC - 2703.1.3 Signals.** The emergency control station shall receive signals from emergency equipment and alarm and detection systems. Such emergency equipment and alarm and detection systems shall include, but not be limited to, the following where such equipment or systems are required to be provided either in this chapter or elsewhere in this code:
  1. Automatic sprinkler system alarm and monitoring systems.
  3. Emergency alarm systems.
  4. Continuous gas detection systems.
  5. Smoke detection systems.
  6. Emergency power system.
  7. Automatic detection and alarm systems for pyrophoric liquids and Class 3 water-reactive liquids required in Section 2705.2.3.4 of the International Fire Code.
  8. Exhaust ventilation flow alarm devices for pyrophoric liquids and Class 3 water-reactive liquids cabinet exhaust ventilation systems required in Section 2705.2.3.4 of the International Fire Code.
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**IBC - 415.11.3.5 Emergency alarm system.** Emergency alarm systems shall be provided in accordance with this section and Sections 415.5.1 and 415.5.2. The maximum allowable quantity per control area provisions shall not apply to emergency alarm systems required for HPM.

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TOXIC GAS DISTRIBUTION AND TGM INTERFACE
TOXIC GAS DETECTED IN THE TOOL EXHAUST
TOXIC GAS DETECTED IN THE VMB EXHAUST
TOXIC GAS DETECTED IN THE GAS CABINET EXHAUST
TOXIC GAS MONITORING FOR TOOL’S WITH ONBOARD GAS BOTTLES
TOXIC GAS MONITORING BLOCK DIAGRAM
TOXIC GAS MONITORING SYSTEM OVERVIEW

PLC Specifications:
- Redundant Power Supplies
- Redundant CPU’s
- Redundant Communication

- FTP and Ethernet IP (Redundant)
- Discrete I/O
- 24VDC
- 4-20mA
- Fault Signal Discrete I/O
- TCP/IP
- Control Room SCADA
- TGM Manual Pull
- Tool CO₂ Fire Suppression
- Fire Alarm System
SEMICONDUCTOR TOXIC GAS MONITORING SYSTEM SIZE

- PLC MAIN CONTROL PANELS ~ 4
- PLC REMOTE INPUT/OUTPUT PANELS ~ 60
- TOXIC GAS MONITORING FTIR AND CHEMCASSETTE DETECTORS ~ 50
- SINGLE POINT DETECTORS ~ 1200
- TOXIC GAS MONITORING DETECTION POINTS ~ 3500
- DISCRETE I/O POINTS ~ 8500
## Detector Technology

**GAS TYPES**

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<th>HOT WIRE</th>
<th>CATALYTIC BEAD</th>
<th>ELECTRO-CHEMICAL (EC CELL)</th>
<th>PYROLYZER / EC CELL</th>
<th>COLORIMETRIC TECHNOLOGY CHEM CASSETTE</th>
<th>SOLID STATE SENSORS</th>
<th>GALVANIC SENSORS</th>
<th>FOURIER TRANSFORM INFRARED SPECTROMETER (FTIR)</th>
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1- Combustible Levels  
2- Freon Dependent  
3- Not Available with new Arsine TLV  
4- Cross Interferences to Freon's
Chemcassette Detectors are widely used in the Semiconductor industry and are the primary detection method used when detecting for the following gas families:

- OXIDIZERS
  - FLUORINE
  - CHORINE
- HYDRIDES
- MINERAL ACID
FOURIER TRANSFORM INFRARED SPECTROSCOPES

- Can monitor multiple gases with a single detection tube.
- Lower detectable limits for some gases has been an issue meeting code required set points.
- Sequential monitoring per point:
  - Longer to cycle time to get through all the points depending on how many gases each sample point is monitoring for.
SINGLE POINT MONITORS

PRIMARY USED TO DETECT:

- LEL - LOWER EXPLOSIVE LIMIT DETECTION
- Si2H6 - DISILANE
- O3 - OZONE
- O2 - OXYGEN
- NF3/W PYROLYZER - NITROGENTRIFLUORIDE
- NH3 - AMMONIA

- Great flexibility for installs
- Susceptible to cross detections
CONCLUSION